PILOT MONITORING OF BLACK CARBON CONCENTRATIONS IN SOME HIGH RISE APARTMENTS IN HANOI

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Abstract: *Black Carbon (BC) is an important byproduct resulted from the incomplete combustion of biomass and fossil fuels commonly referred to as soot. BC pollution not only contributes to the climate change but also impacts seriously to human health. In Vietnam, due to strong urbanization process, the number of vehicles is increasing rapidly and vehicle emission becomes the major cause of air quality degradation in major cities, including Hanoi. Several studies have been mentioned to air pollutants in Hanoi. However, to our knowledge, no research has been attempted on to measure levels of BC in Hanoi residential buildings. Therefore, in this pilot study, two state_of_art instruments-AethLabs model AE51, for the first time, have been used to simultaneously and continuously measure both indoor and outdoor BC concentrations at two high rise apartments in Hanoi to quantify and initially develop the understanding of factors driving BC levels. Daily average indoor and outdoor BC concentrations ranged from 4028 to 4578 ng/m^3 and from 4206 to 4984 ng/m^3, respectively. Statistic analysis and the subsequent inspection of time series of BC concentrations and their I/O ratios showed that outdoor BC concentrations were strongly influenced by the outdoor vehicle emissions, especially heavy diesel power trucks, while indoor BC concentrations were contributed by both indoor and outdoor sources.*

Keywords: *Black Carbon, high rise apartment, traffic emission, wind direction, cooking activities.*

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1. Introduction

Black Carbon (BC) is drawing more interest from scientists and environmental policy makers worldwide. It is because BC is one of the air pollutants that affect both climate change and human health [1,2]. In terms of adverse impacts on human health, BC has been seen as one of the most important air pollutants as it can penetrate into sensitive regions of the respiratory system, and can cause or aggravate cardiovascular and lung diseases [3-6]. Particularly, [6] showed that BC is a main present in the ultrafine fraction of particulate matter (particles with diameter less than 0.1 μm). Due to their small sizes, they can be transported through the respiratory tract and across the lung membranes, affecting serious human health. Moreover, once BC ultrafine particles absorbed into the bloodstream they can move to other organs. During their formation, BC particles can be attached to toxic or even carcinogenic substances, for example polycyclic aromatic hydrocarbons-PAHs [4]. BC is the major component of diesel exhaust, which has been classified as carcinogenic [2]. In addition, gas cooking [7] and combustion of incenses, candle and anti-mosquito coils [8] also emit large amount of indoor BC. Significant population growth and urbanisation have been experienced by most large cities in Vietnam, including Hanoi. New approaches to land and urban planning are needed in order to accommodate significant population growth, however such approaches, which include transit oriented urban development, can increase the number of buildings, especially high rise residential apartments located close to transport corridors. Given that outdoor particles can penetrate the building envelope via doors, windows, building structure leakages and ventilation systems, the exposure of building occupants to outdoor particles is on the rise. [9,10] studied ultrafine particle concentrations and factors driving them at some high rise apartments in Hanoi. However, according to our knowledge, there is no publication on BC at high rise residential apartments in Vietnam. Therefore, this study aims to: (1) quantify the indoor and outdoor BC concentrations in two different high rise apartments in Hanoi; (2) initially evaluate factors influenced BC concentrations at these apartments.

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2. Methods

2.1 Study area and measured locations

Study area is in Hanoi, capital city of Vietnam, with its locations, geographic and climate conditions was described in detail in [10]. In Hanoi, motorbikes are the main transport mode that people use for travelling. The number of motorbikes and cars in Hanoi has increased rapidly in recent years, surpassing the growth rates of population, GDP, and the growth of automobiles will continue to grow for years ahead.

Recently, high rise apartments were also raised rapidly to satisfy the living demand of high population. Of which, many buildings locate closed to busy traffic roads.

To evaluate indoor and outdoor BC concentrations, two different high rise apartments closed to busy roads were selected to measure, of which one in the Phap Van urban area, other in Duong Noi urban area, and named them as site S1 and S2, respectively. Remarkable that these sites were also chosen to measure particle number concentrations at our previous study [9]. Both selected apartments use gas stoves for daily cooking.

Site S1 locates in the eight floor of the high rise apartment in the Phap Van urban area. The building is about 120 m in the west of the National Express way No1B, and about 1000 m in the south of the ring road No3.

Sites S2 locates in the twelve floor of the high rise apartment in Duong Noi urban area. The building locates about 100 m in the west of To Huu street, and 300 m from the south of Le Trong Tan road.

2.2 Instrumentation and quality assurance

Two microAeth portable aethalometers (AethLabs model AE51) were used to measure continuously and simultaneously indoor and outdoor BC concentrations at each apartment for at least 48 h. The AE51 is the standard instrument for measuring BC concentration. It is relatively light (280g, 117 mm x 66 mm x 28 mm). The operational principal of the AE51 bases on the fraction of carbonaceous aerosol that absorbs light at a wavelength of 880nm. It was quantified by measuring the attenuation light transmitted through samples collected on a fibrous filter and by adopting the “specific attenuation” to convert the absorbed light in the filter to BC mass [11].

The AE51s were calibrated by the manufacturer prior to the study. We set it to a flow rate of 100 mL/min and logged average BC concentrations every 30 second. The settings were based on initial tests that indicated they were best compromise between battery life, temporal resolution, and signal to noise ratio.

2.3 Sample sites and measurement procedures

One AE51 measured continuously at the outside of each apartment. The second measured simultaneously inside the rooms of this house. At the same time, a data logging sheet was supplied to a house member; and requested him/her to fill the sheet when any inside activity occurred. The logging sheet then was collected for data interpretation.

Site 1:

One AE51 continuously measured at a balcony of level 8, about 26 m height, catching up outdoor BC concentration. The other measured simultaneously at the same level inside a combined living and dining room from 9-13 September 2016. Locations of samples at Site 1 are shown in [9].

Site 2:

One AE51 continuously measured at a balcony of level 12, about 41 m height, catching up outdoor BC concentration. The other measured simultaneously at the same level and inside a combined dining and kitchen room from 20-22 September 2016. Locations of samples at Site 2 are shown in [9].

2.4 Meteorological data

Meteorological data (temperature, relative humidity, wind components and rainfall) for the monitoring period were acquired from the meteorological station of the Hanoi International Airport, which is located 15-20 km from the sample sites.

2.5 Data preparation and analysis

Data from each AE51 was downloaded after each measurement and tested to make sure no any system error occurred during the sampling. The collected data were grouped according to their location, and

classified by measured time in to Rush_hours from 6:30 to 8:30 and 16:30 to 18:30; Midnight hours from 21:30 to 1:00 of the next day; and the remaining is Non Rush_hours to analyse the influence of different outdoor sources. The ratios of indoor and outdoor BC concentrations were calculated on a sample-by-sample basis, and then averaged (not calculated as the ratio of the means). All statistical analyses consisting of student t-test and one way Anova were performed with SPSS version 20 (SPSS Inc.), with a 5% level of significance ($p<0.05$).

3. Results and discussion

3.1 Outdoor BC concentrations

Descriptive statistics of outdoor BC concentrations during Rush_hours, Non Rush_hours, Midnight and Entire measurement periods are presented in Table 1; and their time series are presented in Fig. 1. General mean outdoor concentrations at Site 1 and Site 2 were 4206±1440 and 4984±2456 (ng/m^3), respectively. These concentrations were relevant to those measured in ambient atmosphere in Beijing (4400±3700ng/m^3) [12] and Shanghai, China (5470±4000 ng/m^3) [13], and significantly higher than those measured in Bacerlona, Spain (mean=1871 ng/m^3) [14] and Brisbane, Australia (1073±3823 ng/m^3) [15].

According to daily time segments, average BC concentrations during Non Rush_hours were significantly lower than those during Rush_hours and Midnight at both sites ($p<0.05$). While mean outdoor BC concentrations during Rush_hours and Midnight were not significantly different at Site 1 ($p=0.64$); mean Midnight outdoor BC concentration was significantly higher than those at the Rush_hours at Site 2 ($p<0.05$). The higher outdoor concentrations during Rush_hours compared to Non Rush_hours can be explained by higher traffic condition during these periods. At the same time, higher levels of BC concentrations during Midnight were also understood by the entry of larger diesel trucks into the city at this time.

While outdoor BC concentrations at Site 1 during Non Rush_hours were not significantly higher than Site 2 ($p=0.43$); both BC concentrations during Rush_hours and midnight at Site 1 were lower than those at Site 2, even though the vehicular density on the roads closed to Sites 1 were higher than the roads close to Site 2 [9,10]. During the measuring at Site 1, the main wind directions were North and Northern West. These made the Site 1 upwind of No1 express way, which was denoted as the main outdoor sources of particles [9,10]. While the main wind directions during the measurement at Site 2 were North and Northern East. It made Site 2 downwind and strongly influenced by night heavy trucks from the Le Trong Tan road. On the other hand, during the monitor at both sites, recorded rainy events were very rare and usually occurred in a very short time. It, hence, can be denoted that the wind direction was a main metrological factor and strongly affected to outdoor BC concentrations in these study.

3.2 Indoor BC concentrations

Descriptive statistics of indoor BC concentrations according to daily time segment and their time series are presented in Table 2 and Fig. 1 and 2, respectively. Average indoor BC concentrations at Site 1 and Site 2 were 4028±957 and 4576±1810 (ng/m^3), respectively. These concentrations were higher than those measured inside the houses in Barcelona, Spain (mean=1572 ng/m^3) [14] and Brisbane, Australia (1087±501 ng/m^3) [15].

Non Rush_hours indoor BC concentrations were significantly lower than those at Rush_hours and Midnight at both sites ($p<0.05$). While at Site 1, BC levels were not significantly different during Rush_hours and Midnight ($p=0.64$), at Site 2, midnight BC concentrations were significantly higher than those during Rush_hours ($p<0.05$). It can be explained by the higher outdoor concentrations and their dominant impact on the indoor BC levels during this time at Site 2.

Table 1. *Descriptive statistics of outdoor BC concentrations (ng/m^3)*

	Site 1				Site 2			
	Non_ Rush	Rush_ Hour	Midnight	Whole	Non_ Rush	Rush_ Hour	Midnight	Whole
Mean	3947	4657	4567	4206	4008	5543	8506	4984
SD	1324	1693	1319	1440	1731	2083	2136	2456
Max	11370	10303	7451	11370	11021	11145	14090	14090
Min	1626	1935	1258	1258	1924	2392	3542	1924

Table 2. *Descriptive statistics of indoor BC concentrations (ng/m^3)*

	Site 1				Site 2			
	Non_ Rush	Rush_ Hour	Midnight	Whole	Non_ Rush	Rush_ Hour	Midnight	Whole
Mean	3876	4286	4248	4028	3906	4895	7080	4576
SD	928	954	956	957	1347	1544	1572	1810
Max	8319	7987	8234	8319	8418	10077	11425	11425
Min	1730	2520	1163	1163	2286	2469	3103	2286

Table 3. *Descriptive statistics of indoor/outdoor BC concentrations ratios (I/O)*

	Site 1				Site 2			
	Non_ Rush	Rush_ Hour	Midnight	Whole	Non_ Rush	Rush_ Hour	Midnight	Whole
Mean	1.05	1.00	0.97	1.02	1.01	0.92	0.85	0.97
SD	0.30	0.32	0.23	0.30	0.16	0.21	0.12	0.18
Max	2.80	2.45	2.43	2.80	1.93	2.04	1.20	2.04
Min	0.27	0.53	0.42	0.27	0.65	0.58	0.60	0.58

3.3 I/O ratios of BC concentrations

Min, max, average and standard deviation of I/O ratios for BC concentrations at Site 1 and Site 2 are presented in Table 3. Simultaneously, their time series values are presented in Fig. 1 and Fig. 2 for Site 1 and Site 2, respectively. General average I/O ratios at Site 1 and Site 2 were 1.02±0.30 and 0.97±0.18, respectively. These concentrations were relevant to those calculated by Viana et, al, (mean=0.97) [14], which BC levels were measured in a 40 year old building with inadequate insulation; and higher than values for European urban environment, which from 0.60 to 0.65 [16]. The high I/O ratios in this study can be understood by opening windows for natural ventilation during the cool autumn weather.

I/O ratios during Non Rush_hours were significantly higher, while ratios during Midnight were significantly lower than other time periods ($p<0.05$). In addition, the values of standard deviations during Midnight were lower, while the values during Rush_hours were higher than others. It can imply that indoor BC concentrations were mainly influenced by outdoor sources during midnight, and by other indoor sources during Rush_hours and Non Rush_hours. Look at the time series data (Figs. 1,2), we can see that the I/O ratios were usually higher than 1 during early morning (5:00-7:00) and later afternoon (18:00-19:30). It can infer that using gas stoves for breakfast and dinner cooking has significantly contributed to indoor BC levels.

4. Conclusions

The first time, both indoor and outdoor BC concentrations were quantified at two high rise apartment buildings in Hanoi, and factors driving them were initially evaluated. Outdoor vehicular emissions, especially heavy diesel trucks strongly influenced outdoor and indoor BC concentrations. In addition, wind directions also took a very important role to transport BC pollutants into the urban ambient atmosphere. Furthermore,

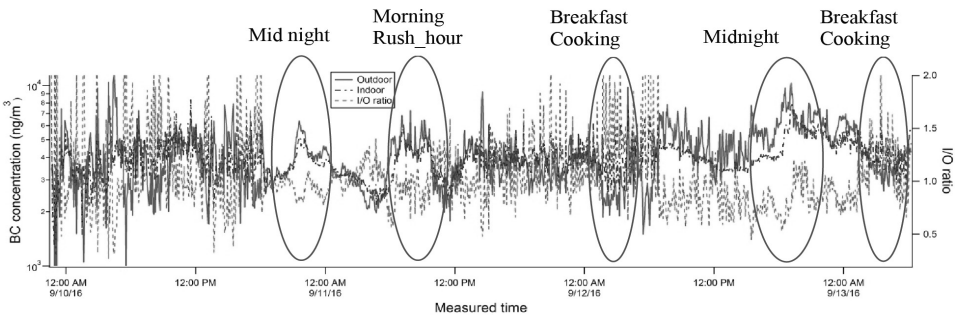

Figure 1. *Time series of Site 1's indoor/outdoor BC concentrations and their ratios*

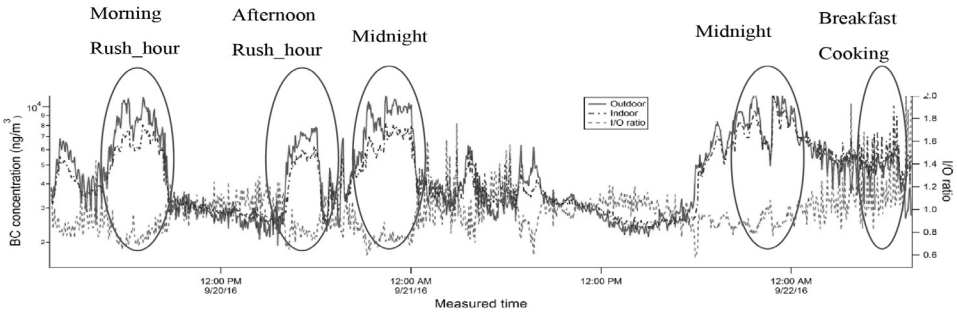

Figure 2. *Time series of Site 2's indoor/outdoor BC concentrations and their ratios*

the habit to open windows for naturally ventilation at residential buildings can raise the indoor BC levels. At the same time, gas cooking activities were recognized as another factor affected indoor BC concentrations.

The present study could be developed for larger number and longer measured experiments to catch up a general and clearer picture of BC pollutants, their characteristics and behaviours under different influenced factors in Hanoi.

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